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## **PRECAST SLABS FOR CONTINGENCY RIGID AIRFIELD PAVEMENT DAMAGE REPAIRS (BRIEFING SLIDES)**

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<b>14. ABSTRACT</b> <p>A significant number of airfield pavements are constructed with Portland cement concrete. Proper serviceability of concrete slabs is restored by scheduled maintenance, which allows for optimal aircraft operations. Catastrophic damage of military airfield pavements in austere conditions, on the other hand, requires a well formulated contingency plan to efficiently and effectively restore the damaged sections. This study investigates the feasibility and efficiency of using different precast concrete panel installation techniques for contingency repair of damaged airfield pavements. Fast-setting polymer foam and flowable fill were selected as bedding materials and bonding agents after review of the literature. A deep-injection method as well as conventional leveling was used to account for the impact of leveling techniques in the experiment design.</p> <p>Performance of the repaired sections was characterized by load transfer efficiency, joint stiffness and deformation energy dissipated through the pavement foundation. A heavy weight deflectometer (HWD) and a military aircraft gear simulator were used to determine the stiffness properties and accumulation of plastic deformations after each load interval. Decay of joint stiffness and load transfer efficiency as well as increase in deformation energy were calculated as a function of number of load applications.</p>						
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# **PRECAST SLABS FOR CONTINGENCY RIGID AIRFIELD PAVEMENT DAMAGE REPAIRS**

**23 March 2010**

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## Load Transfer in Rigid Pavements



- **Definition:**
  - "Load transfer" is a term used to describe the transfer (or distribution) of load across discontinuities such as joints or cracks (AASHTO, 1993).
- **Factors Influencing the Load Transfer:**
  - Loading condition
  - Foundation support
  - Stiffness and thickness of the concrete slab
  - Load transfer mechanism
    - Aggregates
    - Dowel bars
  - Temperature (affects joint opening)
  - Joint spacing



## State of the Problem



- **To Assess the load transfer capability of repaired slabs using different pre-cast methodologies**
  - Slab #1: High-density polyethylene (HDP) foam
  - Slab #2: Deep injection
  - Slab #3: Flowable fill
- **This objective is achieved through analysis of the heavy weight deflectometer (HWD) results for each slab**
- **Following criteria were considered in the analysis:**
  - Load transfer efficiency based on deflections ( $LTE_{\delta}$ )
  - Load transfer efficiency based on stresses ( $LTE_{\sigma}$ )
  - Load transfer based on FAA design criteria ( $LT$ )
  - Analysis of joint stiffness for each variant
  - Deformation energy method (DE)

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This project is about the technology of using precast concrete panels for the repair of concrete pavements.

Major advantage of pre-cast panels is the reduction in construction time while maintaining proper mechanical performance.

Pre-cast panel replacement technique is a suitable solution for rapid repair of airfield pavements.



## Sensitivity Analysis LTE Model

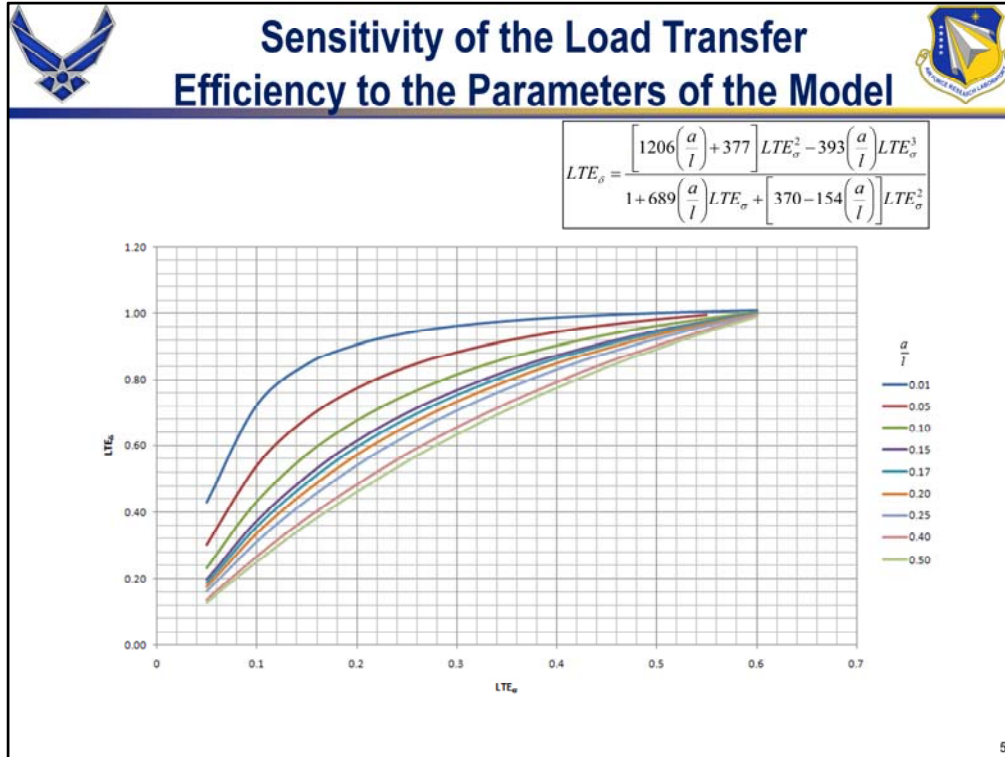


$$LTE_{\sigma} = \frac{\left[ 1206 \left( \frac{a}{l} \right) + 377 \right] LTE_{\sigma}^2 - 393 \left( \frac{a}{l} \right) LTE_{\sigma}^3}{1 + 689 \left( \frac{a}{l} \right) LTE_{\sigma} + \left[ 370 - 154 \left( \frac{a}{l} \right) \right] LTE_{\sigma}^2}$$

E (psi)	1,000,000	1,500,000	2,000,000	2,500,000	3,000,000	3,500,000	4,000,000	4,500,000	5,000,000
l	25.82	28.57	30.71	32.47	33.98	35.32	36.51	37.61	38.61
a/l	0.23	0.21	0.20	0.18	0.18	0.17	0.16	0.16	0.16

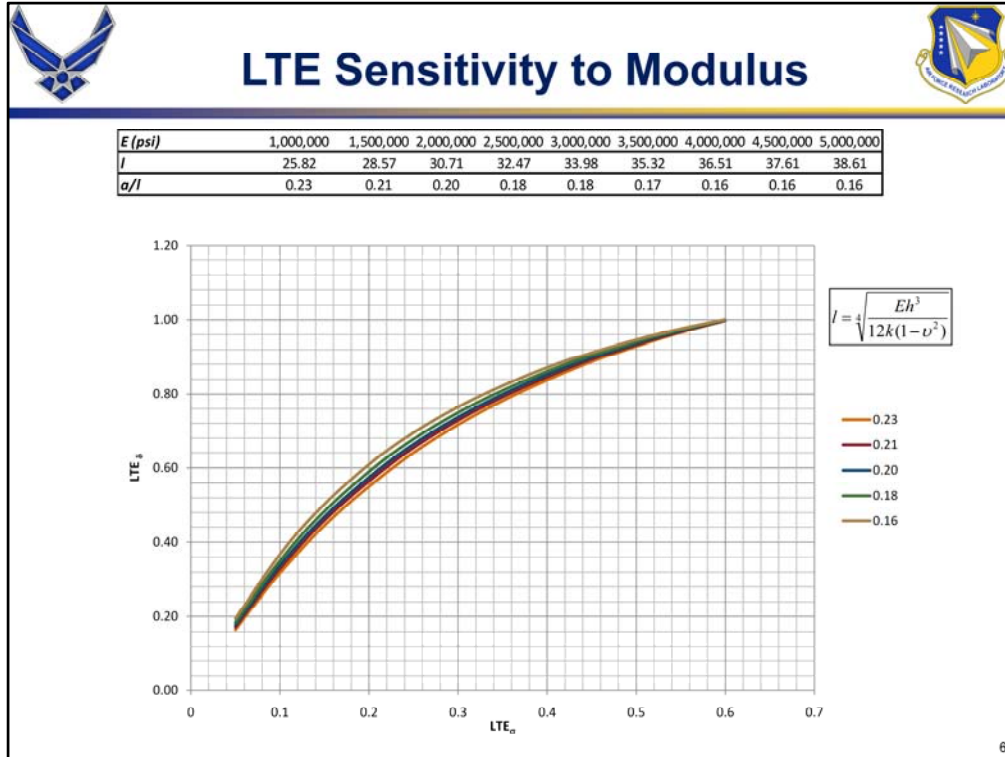
		a/l								
		0.01	0.05	0.10	0.15	0.17	0.20	0.25	0.40	0.50
LTE <sub>σ</sub>	0.05	0.43	0.30	0.23	0.20	0.19	0.18	0.16	0.14	0.13
	0.1	0.72	0.54	0.43	0.37	0.36	0.34	0.31	0.27	0.25
	0.15	0.85	0.68	0.57	0.51	0.49	0.47	0.44	0.38	0.36
	0.2	0.91	0.77	0.68	0.61	0.60	0.57	0.54	0.48	0.46
	0.25	0.94	0.84	0.75	0.70	0.68	0.66	0.63	0.57	0.55
	0.3	0.96	0.88	0.82	0.77	0.75	0.73	0.71	0.66	0.63
	0.35	0.98	0.92	0.86	0.83	0.81	0.80	0.77	0.73	0.71
	0.4	0.99	0.94	0.90	0.87	0.86	0.85	0.83	0.79	0.78
	0.45	1.00	0.97	0.94	0.91	0.91	0.90	0.88	0.85	0.84
	0.5	1.00	0.98	0.96	0.95	0.94	0.94	0.93	0.90	0.89
	0.55	1.01	1.00	0.99	0.98	0.97	0.97	0.96	0.95	0.95
	0.6	1.01	1.01	1.00	1.00	1.00	1.00	1.00	0.99	0.99

Sensitivity Analysis of the parameters of the LTE model.



Looking at the whole range of  $a/l$ , shows the LTE is sensitive to  $a/l$  parameter.

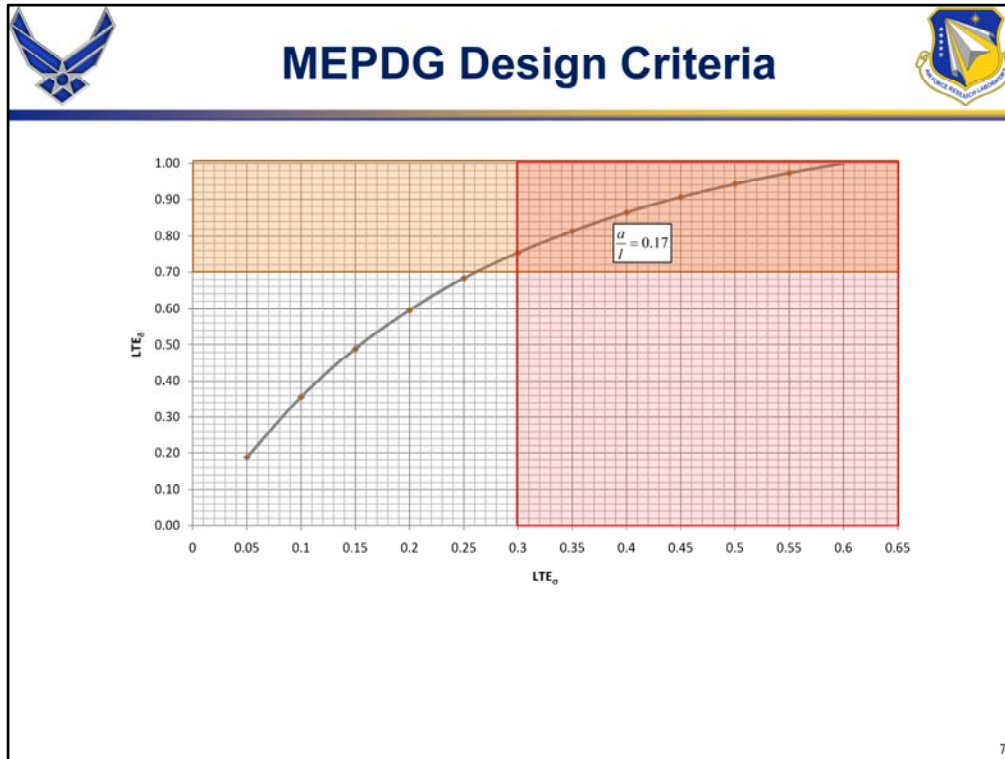
This slide shows the sensitivity of the stress-based and deflection based load transfer efficiency with respect to the load size ratio ( $a/l$ ). This plot indicates that the gradient of the  $LTE_{\delta}$ - $LTE_{\sigma}$  curves are higher when the load acts on a small area such as concentrated or point loads; however, larger load prints are shown to have lower sensitivity to the ( $a/l$ ) value which is in conformity with finite element analysis results by Korovesis.



For plate loading with  $r=6$  in  $k=100$  pci and  $h=9$  in,  $LTE$  is not very sensitive to modulus of the pre-cast concrete (PCC) slab.

The trends in this figure clearly indicate that  $LTE_d$ - $LTE_s$  curves are not sensitive to the values of PCC modulus for  $a=5.9$ . As previously shown in previous slide, area of the load has the most impact on the sensitivity of the  $LTE_d$ - $LTE_s$  curves.

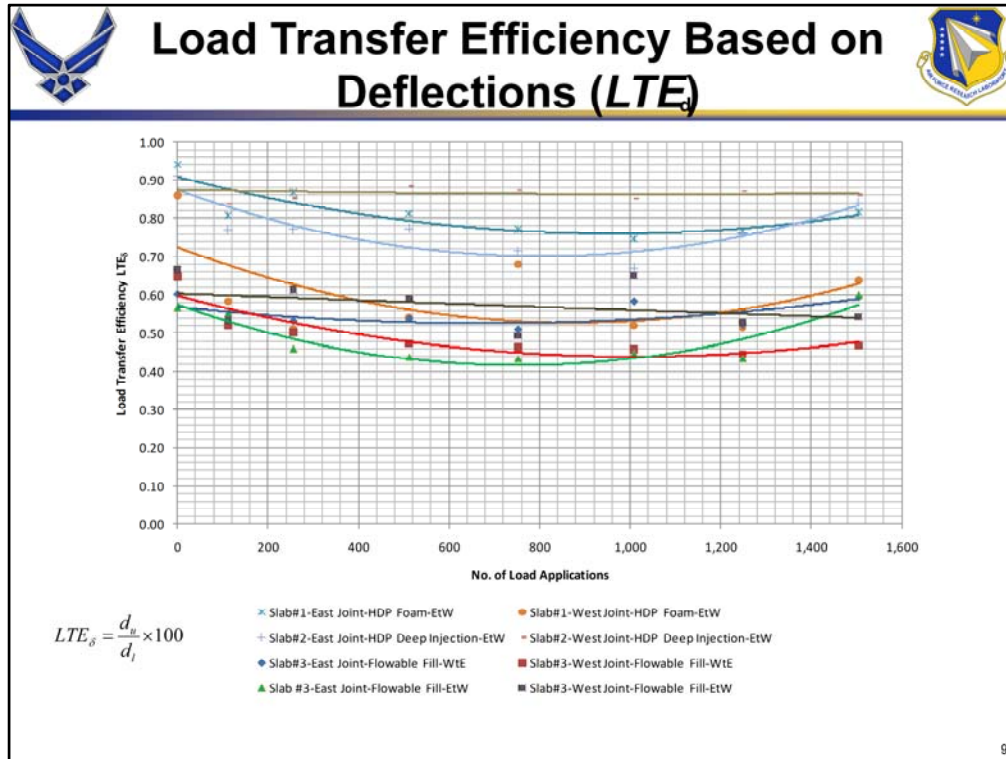




Design chart based on Mechanistic-Empirical Pavement Design Guide (MEPDG) design criteria.



This slide shows the placement of the HWD at the joint for determination of LTE. This slide shows the impact load is located at the edge of the loaded slab at the right side of the picture and geophones were placed 12 inches apart on the unloaded slab.

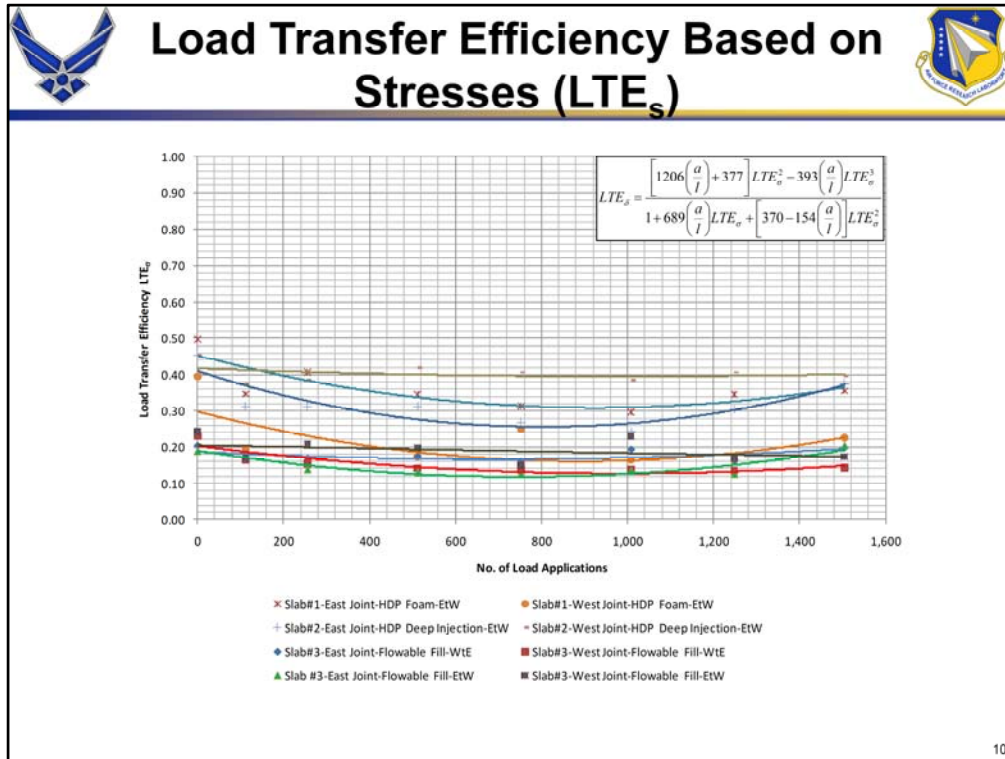


This slide presents the trends of  $LTE_d$  based on direct measurements of plastic deformations using the HWD.

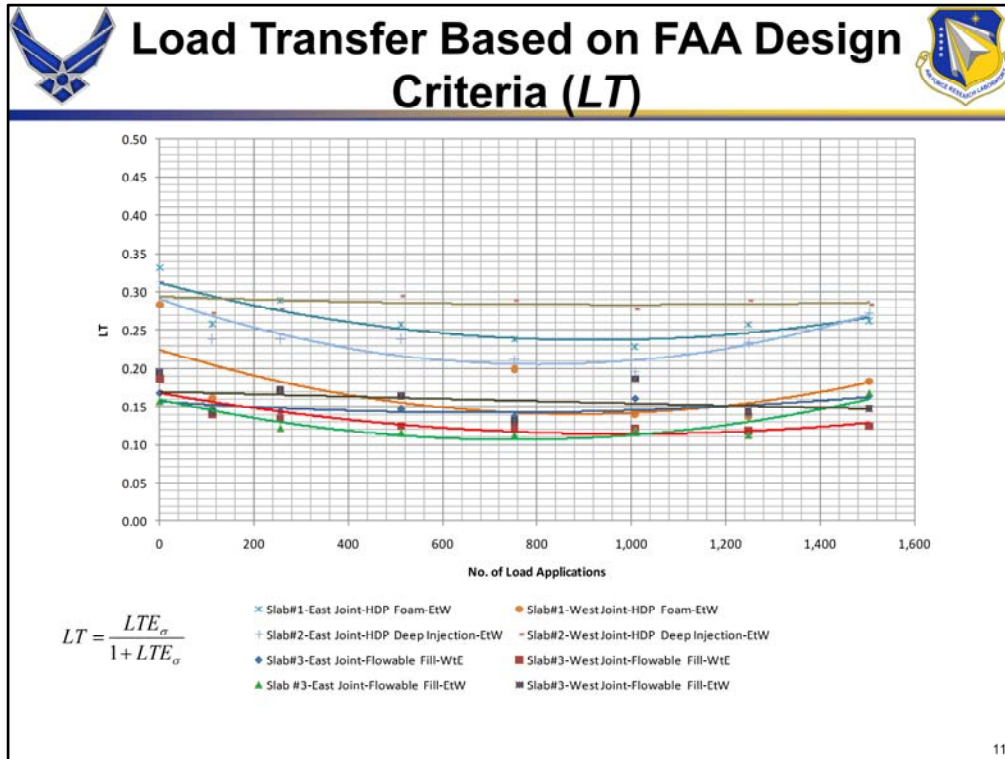
The measurements were taken at two sides of the joints. In other words, at each load interval, the HWD was placed at each side of the joints and directional load transfer efficiencies were determined.

As illustrated in this slide, load transfer at the west joint of Slab #2 installed with deep-inject method had the highest value of load transfer efficiency throughout the testing period. The calculated values of the deflection based load transfer efficiency satisfy the requirement set by MEPDG .

Slab #1 with high-density polyurethane as bonding agent ranked second. Slab #3 with flowable fill was found to perform worst compared to the other design variants.



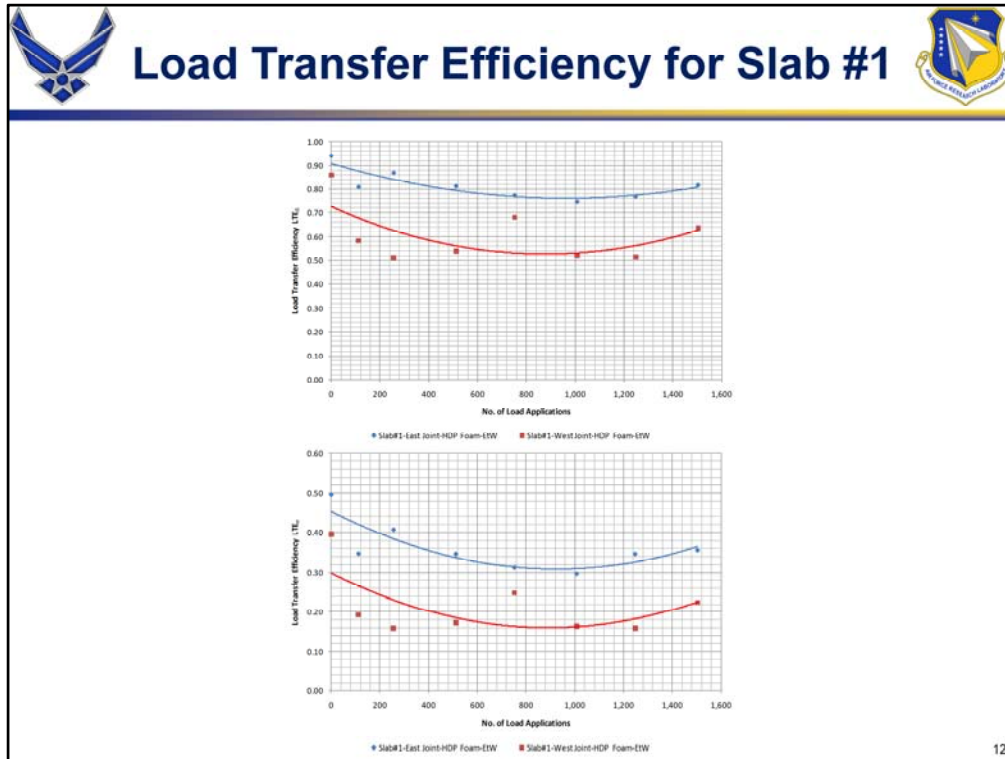
This slide shows the results for load transfer efficiency  $LTE_s$  based on the stress ratios. The results indicate that Slab #2 outperformed slabs #1 and #3 in terms of higher  $LTE_s$  values. Similar to the deflection-based load transfer efficiency, west joint of slab #2 had consistently high values of  $LTE_s$  at various loading intervals. Slab #3 with flowable fill had the lowest load transfer efficiency compared to its counterparts. Repaired sections with higher values of load transfer efficiency are expected to perform better in terms of orthogonal load bearing capacity.



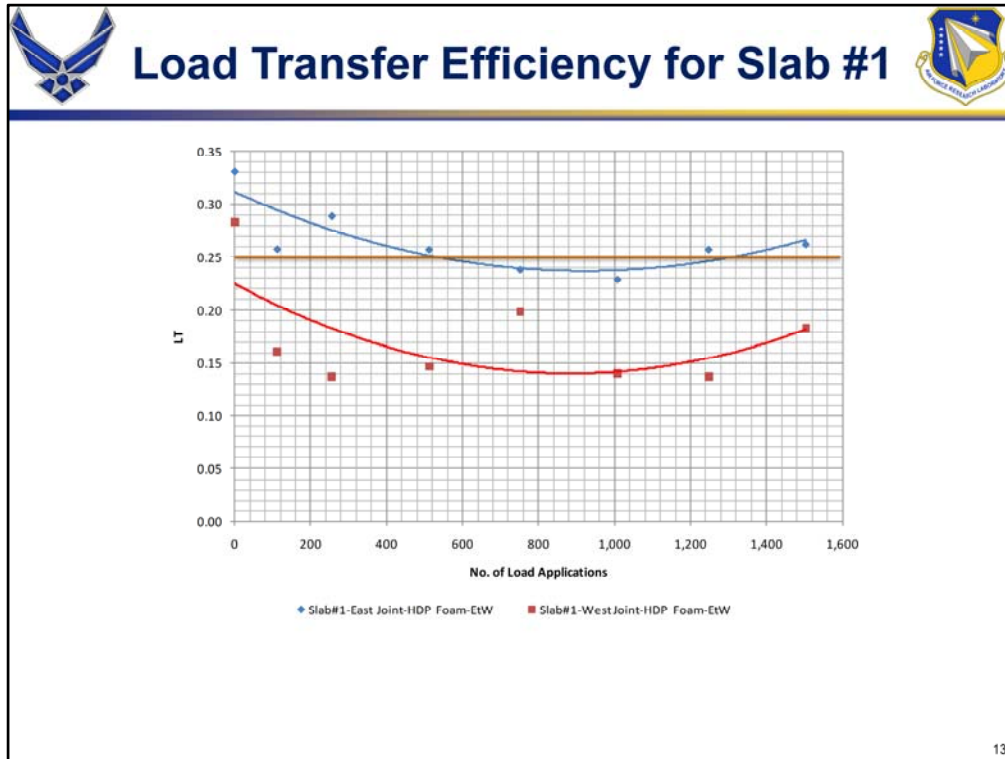
Another stress-based load transfer efficiency criteria is  $LT$  defined by Federal Aviation Administration (FAA).

According to FAA design guide, the acceptable value for  $LT$  is 0.25. The design should be revised if the load transfer does not meet this requirement.

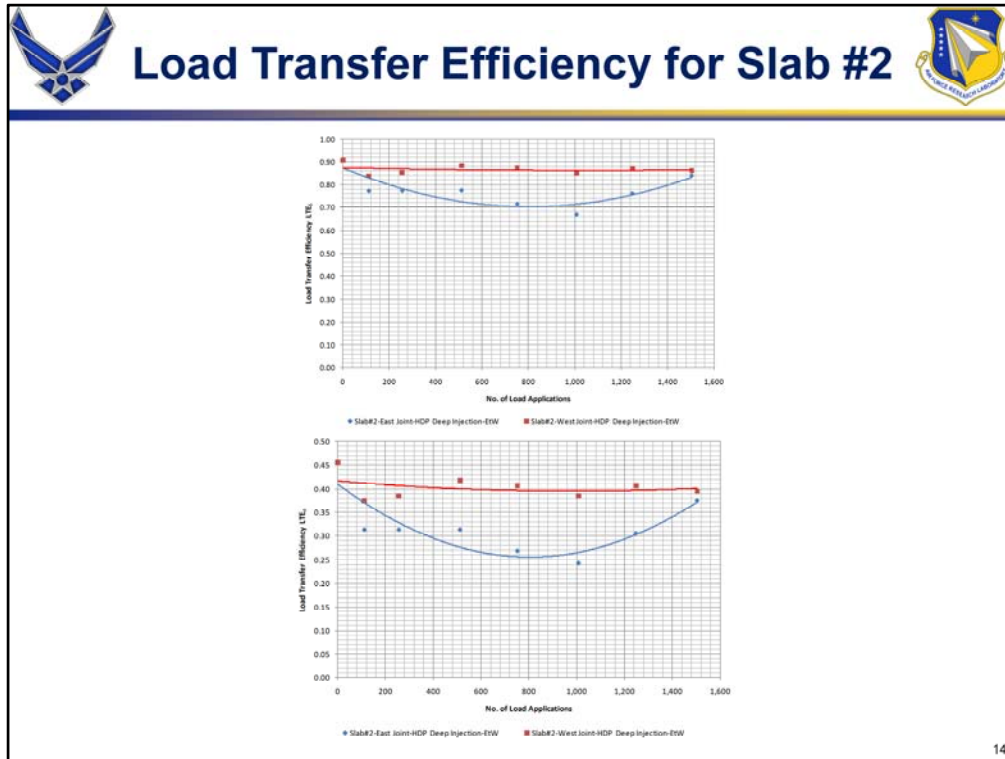
This slide shows the  $LT$  values calculated using equation shown in the left side for the experiment design permutations. The results indicate that slab #2 performs better in terms of load transfer ( $LT$ ) compared to the other counterparts. Slab #1 rank second and slab #3 with flowable fill performs significantly lower compared to slabs with HDP foam.



Comparison between stress based and deflection based load transfer efficiency for slab #1 at east and west joints at different load applications.

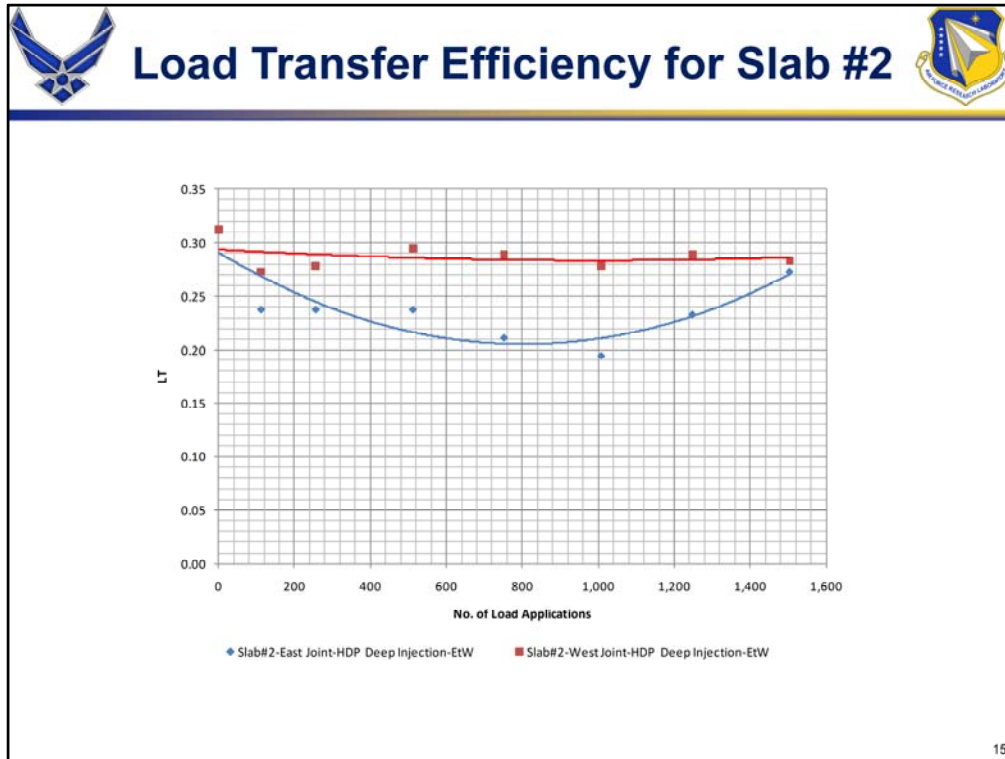


Comparison between FAA load transfer efficiency for slab #1 at east and west joints at different load applications.

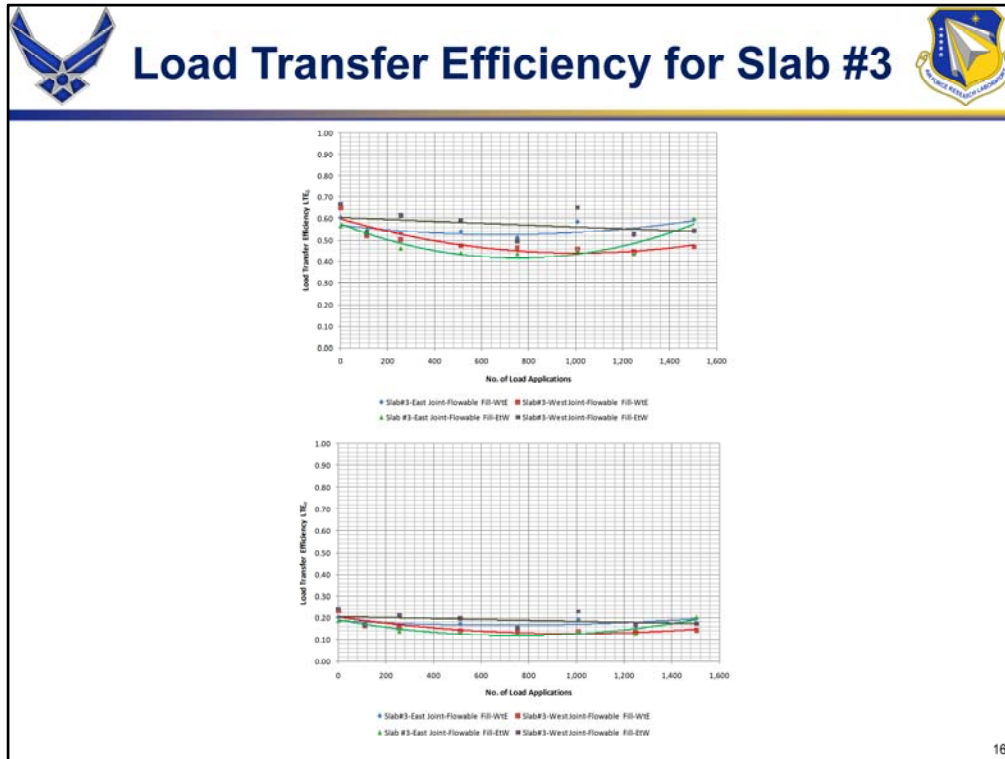


Comparison between stress based and deflection based load transfer efficiency for slab #2 at east and west joints at different load applications.

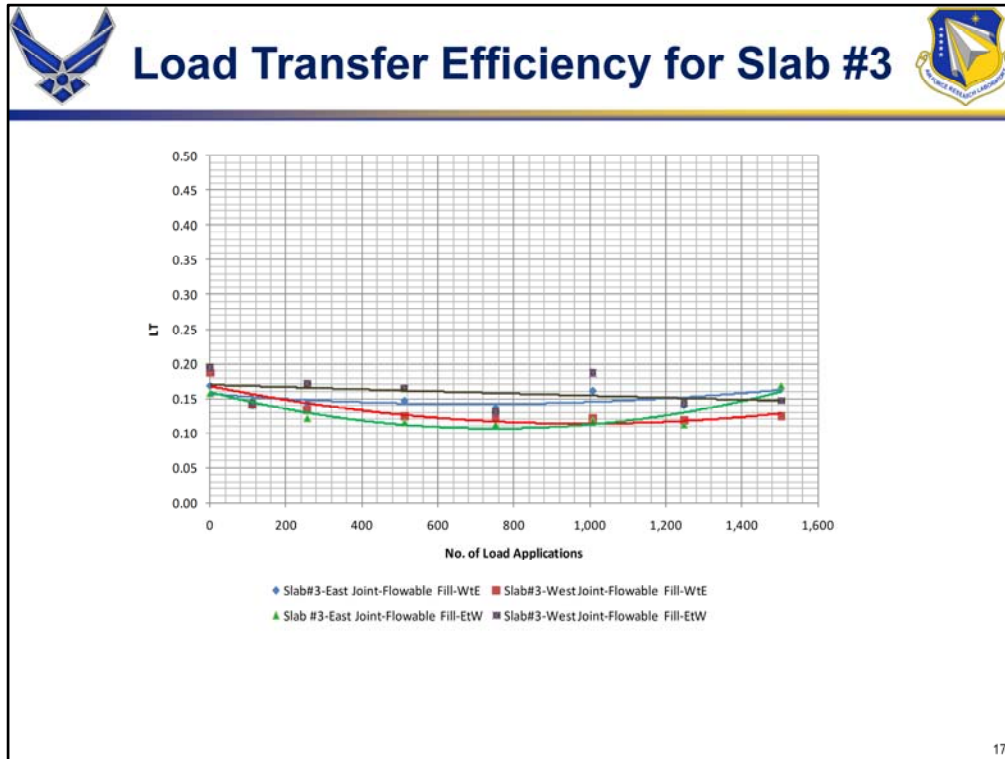




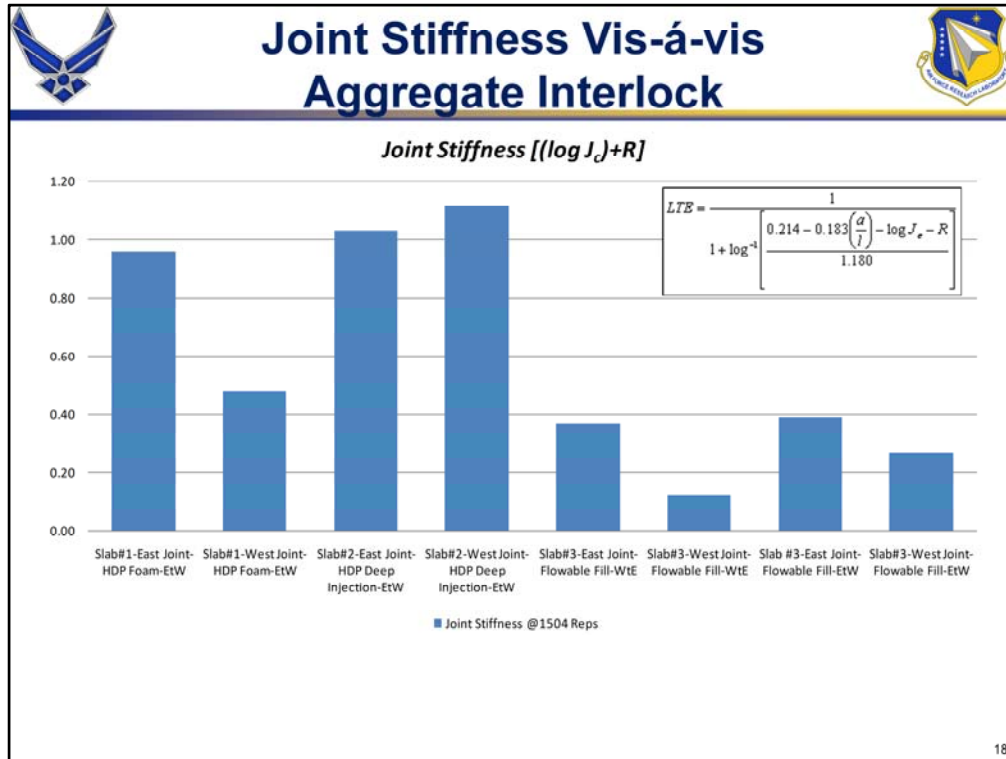
Comparison between FAA load transfer efficiency for slab #2 at east and west joints at different load applications.



Comparison between stress-based and deflection-based load transfer efficiency for slab #3 at east and west joints at different load applications.

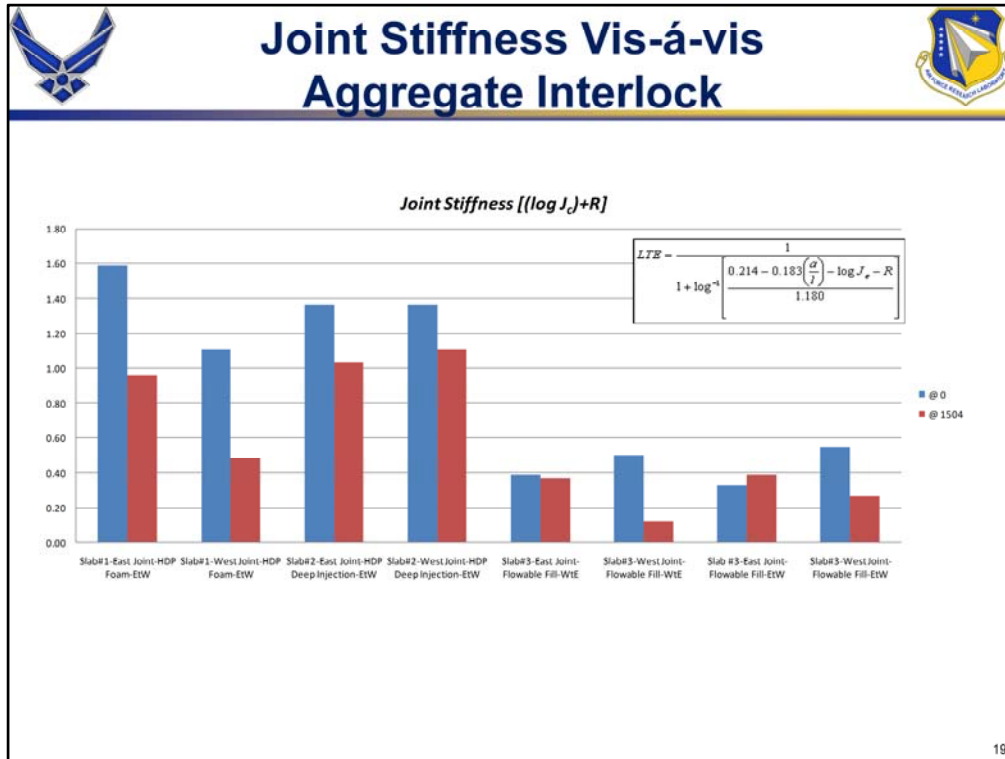


Comparison between FAA load transfer efficiency for slab #3 at east and west joints at different load applications.



Stiffness of the joint is related to aggregate interlock (through friction forces between particles) and also the dowel actions.

This slide shows the joint stiffness values of the design variants after 1504 applications of F-15 load cart. The joint stiffness was assumed to be a function of aggregate interlock and load transfer devices such as dowel bars in the precast panels. The results indicate concrete panels installed by heavy density foam as bonding agent performed better in terms of higher joint stiffness compared to variants installed with flowable fill. On the other hand, slab #2 was found to have higher joint stiffness compared to slabs #1 and #3. This suggests that slab #2 that is installed using deep injection method performed better compared to the other permutations of the design experiment.



This slide shows initial joint stiffness and joint stiffness after 1504 load applications. This plot again confirms that slabs installed with high density polyurethane have better initial and terminal joint stiffness compared to slab #3 installed with flowable fill as bonding agent.

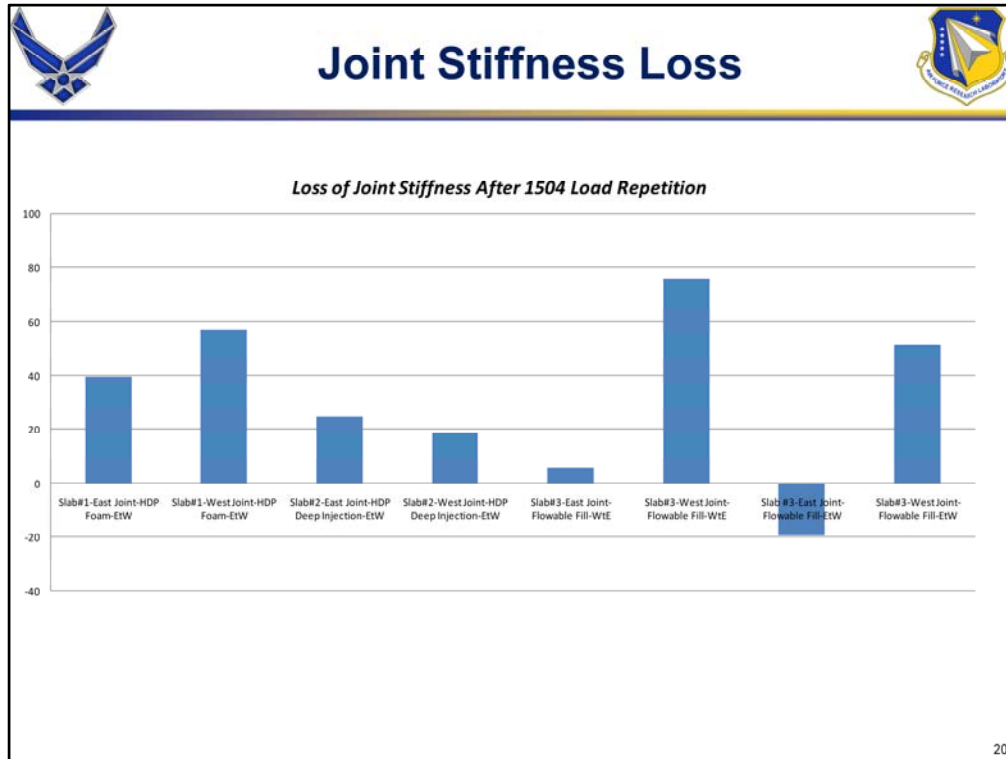


Figure 46 shows the percentage loss of joint stiffness due to 1504 load applications. This plot suggests that deep injection method resulted in better systems in terms of smaller loss of joint stiffness. In other words the gradient of the loss of stiffness in precast panels with high density polyurethane foam and installed with deep injection method is smaller than the other counterparts. The results pertaining to joint stiffness was found to be in conformity with the LTE and LT results presented in previous slides.



## Differential Energy Concept



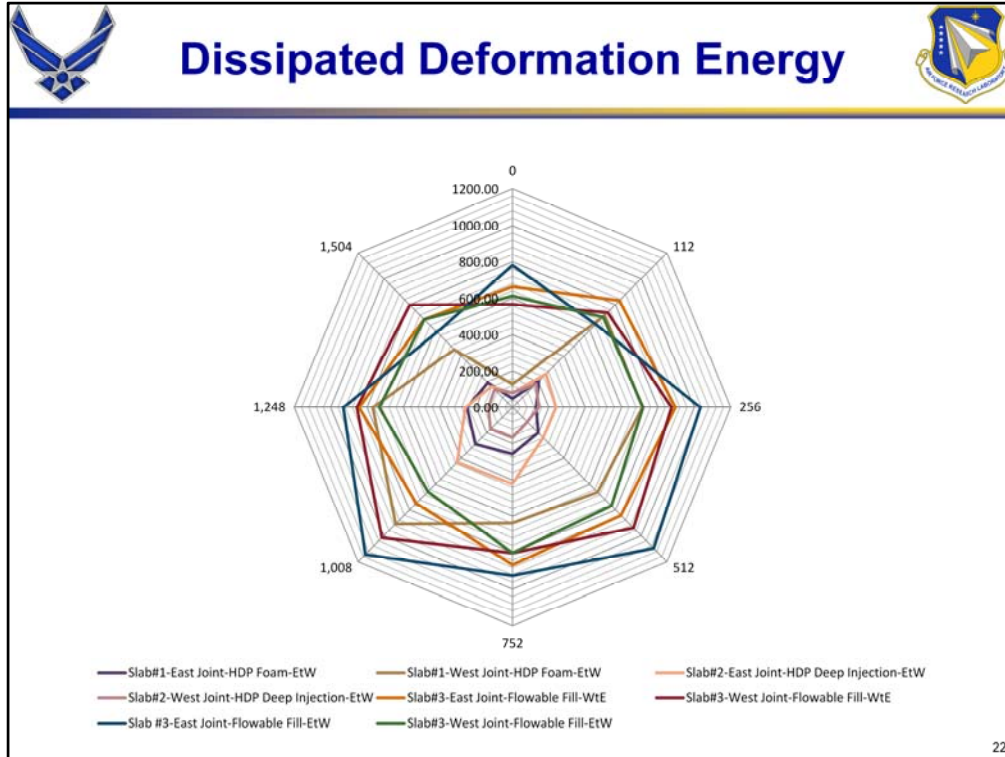
- The energy dissipated to the subgrade is assumed to be proportional to the energy of elastic deformation
- Dissipated energy due to deformation of slab can be written as:

$$E = 0.5k\varepsilon_p^2$$

- $K$  = Modulus of Subgrade Reaction
- $\varepsilon_p$  = Plastic deformation at the edge of the slab
- The differential energy is defined as the energy difference in the elastic subgrade deformation under the loaded slab (leave) and unloaded slab (approach):

$$DE = E_L - E_{UL} = \frac{1}{2}k(\varepsilon_p)_L^2 - \frac{1}{2}k(\varepsilon_p)_{UL}^2$$

- Pavement systems with lower differential energy are expected to perform better in the field.



This slide shows slab #2, west joint installed with deep injection method has the smallest polygon area and therefore performed better in terms of dissipated deformation energy. After polygon referring to slab #2 at west joint, areas of the polygons corresponding to slab #1 have smaller area compared to other permutations of the experiment design as illustrated in figure 47. This suggests that slab #1 at both east and west joints performed superior in terms of lower deformation energy. Slab #3 was found to have the highest area compared to other variants and therefore ranked last in terms of performance based on deformation energy.





## Summary



- Three pre-cast PCC slab installation techniques were investigated in this research effort.
- The installation technique was a combination of Michigan, Super Slab and Uretek® methods.
- High-density polyurethane (HDP) foam was used for leveling and installation of Slabs #1 and #2. Flowable fill was used for Slab #3.
- Performance of the repaired sections were assessed through analysis of:
  - Load transfer efficiency based on deflections ( $LTE_{\delta}$ )
  - Load transfer efficiency based on stresses ( $LTE_{\sigma}$ )
  - Load transfer based on FAA design criteria ( $LT$ )
  - Analysis of joint stiffness based on MEPDG criteria  $[\log(J_c) + R]$
  - Analysis based on dissipated deformation energy to subgrade



## Performance Ranking



*Analysis of the performance of the repaired sections resulted in the following ranking order:*

